A METHOD OF NON-INTRUSIVELY MONITORING THE MIXTURE RATIO
OF A GAS MIXTURE HAVING AT LEAST TWO COMPONENTS

The invention relates to a method of non-intrusively monitoring the mixture ratio of a gas mixture that has at

5   least two components and that is under a pressure of a few bars inside an enclosure.

The invention relates more particularly to monitoring the insulation gas in gas-insulated high-voltage electrical switchgear.

10   BACKGROUND OF THE INVENTION

The insulation gas typically used in such switchgear is sulfur hexafluoride (SF_6). In order to combat global warming due to greenhouse gas emission, the current trend is to mix the SF_6 with some other gas such as nitrogen

15   (N_2) or such as carbon fluoride (CF_4). That type of two-component mixture also improves the breaking performance of electrical switchgear at very low temperatures (-50°C). It is possible that mixtures having more than two components might be used in the future.

20   The ratio of the SF_6/N_2 or SF_6/CF_4 mixture lies approximately in the range 50/50 to 80/20. To maintain a breaking capacity that is satisfactory in electrical switchgear that is insulated with a gas mixture of the N_2/SF_6 or CF_4/SF_6 type, it is essential for the proportion

25   of N_2 or of CF_4 in the gas mixture to remain constant even in the event of leakage. Differential losses between the two components of the mixture can give rise to loss of performance in terms of breaking capacity.

There is also a need for manufacturers of gas-

30   insulated electrical switchgear to specify accurately the ratio of the mixture after filling, in particular in order to satisfy the switchgear rating conditions.

To determine the mixture ratio or else the proportion of one component in a two-component gas

35   mixture, it is known that chromatography or acoustic techniques can be used. However, those methods remain limited to use in the laboratory, and they are not

applicable to on-site monitoring of the insulation gas in electrical switchgear. In addition, those methods are "intrusive" because they require the gas mixture to be tapped, which is not compatible with the operating
5   conditions of gas-insulated electrical switchgear.
OBJECTS AND SUMMARY OF THE INVENTION

An object of the invention is thus to provide a solution that is simple, inexpensive, and non-intrusive for accurately monitoring the proportion of one component
10   relative to the other in a gas mixture having at least two components.

More particularly, an object of the invention is to make it possible to monitor accurately the proportion of N_2 or of CF_4 in an N_2/SF_6 or a CF_4/SF_6 gas mixture serving
15   as insulation gas for high-voltage switchgear.

The monitoring method of the invention makes use of the equations of thermodynamics in particular to determine the proportion of a component in the mixture. It is known that a mixture which is made up of at least
20   two components that have sufficiently different molecular masses is determined entirely by four magnitudes: temperature, pressure, density, and mixture ratio. Tests have shown that, by using commercially-available industrial sensors to measure temperature, pressure, and
25   density, the mixture ratio can be deduced relatively accurately from the resulting measurements by calculation or by table look-up.

The invention thus provides a method of monitoring the proportion of a component in a gaseous mixture having
30   at least two components and contained in an electrical switchgear enclosure, said method consisting in measuring the pressure, the temperature, and the density of the gas mixture by means of sensors mounted on said enclosure, and in determining said proportion by processing the
35   measured values in a data-processing unit, so as to enable the mixture to be monitored non-intrusively.

A magnitude representative of the density of the gas mixture may be measured by means of a vibrating-blade sensor. This type of sensor has two vibrating blades, one in a vacuum and the other in the gas mixture, and it

5   delivers the difference in vibration frequency between the two blades, this frequency difference being representative of the density of the gas mixture. The density of the gas mixture may also be derived from measuring the permittivity of the gas mixture by means of

10   a capacitor or the like, as is well known to the person skilled in the art. The density of the gas mixture may also be derived from measuring the refractive index of the gas mixture by means of an interferometer or the like.

15   BRIEF DESCRIPTION OF THE DRAWING

The method of the invention is described below in detail with reference to the sole figure.

The sole figure is a very diagrammatical view showing a system for monitoring an insulation gas mixture

20   having two components, e.g. N_2/SF_6, in a gas-insulated high-voltage circuit-breaker, and for continuously monitoring the proportion of N_2 in the gas mixture.

MORE DETAILED DESCRIPTION

As shown in the figure, the gastight enclosure 1

25   formed by the metal-cladding of the high-voltage circuit-breaker is filled with an N_2/SF_6 mixture under a pressure of a few bars, and typically in the range 4 bars to 8 bars. A pressure sensor 2 and a density sensor 3 are mounted on the outside wall of the enclosure 1.

30   The pressure sensor 2 continuously delivers a signal P representative of the absolute pressure of the gas mixture in the enclosure. The density sensor 3 continuously delivers a signal ρ representative of the density of the gas mixture and also a signal T

35   representative of the temperature of the gas mixture.

These three signals are sent to a processing unit 4 which delivers as output the proportion of N_2 in the mixture, or in analogous manner the ratio of the mixture.

The mixture ratio, i.e. the ratio between the partial pressures of N_2 and of SF_6 in the mixture may firstly be determined by solving the thermodynamic state equations of the two components of the mixture (Beattie and Bridgman equations).

If P, T, and ρ are the variables measured by the sensors, and X is the mixture ratio to be determined, the Beattie and Bridgman equations for a two-component mixture give the following relationships:

$$P\ SF_6 = A1.\rho\ SF_6 + A2.(\rho\ SF_6)^2 + A3.(\rho\ SF_6)^3$$

$$P\ N_2 = A4.\rho\ N_2$$

$$P = X.\ P\ N_2 + (1-X).\ P\ SF_6$$

$$\rho = \rho\ N_2 + \rho\ SF_6$$

where

A1, A2, A3, and A4 are well-known functions of T;

$P\ SF_6$ and $P\ N_2$ are the partial pressures of N_2 and of SF_6; and

$\rho\ N_2$ and $\rho\ SF_6$ are the densities of N_2 and of SF_6.

On the basis of these equations, the data-processing unit 4 continuously delivers the mixture ratio X as output.

In a variant, the proportion of N_2 relative to SF_6 in the gas mixture may be obtained on the basis of a data table compiled previously during a test campaign. More particularly, a test volume is filled with a gas mixture whose mixture ratio is known. The temperature of the test volume is caused to vary in stages, e.g. from -40°C to +60°C. For each stage, the temperature, the pressure, and the density of the mixture are measured, and the resulting three values are recorded in correspondence with the mixture ratio in the table. These operations are repeated for various mixture ratios. The resulting data table is then loaded and stored in a memory in the unit 4 for the purpose of determining the mixture ratio

as a function of the three measured magnitudes constituted by temperature, pressure, and density.

As indicated above, it is possible to use a vibrating-blade sensor that measures a physical magnitude representative of the density of the gas mixture. In which case, the temperature can be derived from the pressure sensor because modern industrial sensors for measuring pressure deliver both the temperature and also the pressure of the gas being monitored.

The measurements may advantageously be used in a data-processing system 4 in the form of an optionally portable microcomputer installed permanently or temporarily on the enclosure of the electrical switchgear. The unit 4 may also be an electronic circuit having a microprocessor or a microcontroller and integrated in equipment including one or more sensors. The sensors may be physically separated, or else they may be integrated in a common multi-function measurement instrument. In the figure, the sensor 3 provides both the pressure-sensing function and the density-sensing function.

When the data-processing unit 4 is a portable microcomputer, it may be advantageous for said unit to store a plurality of data tables of the type indicated above, each table being specific to a respective gas mixture. In addition, the unit 4 may advantageously be programmed to run algorithms for correcting errors and drift specific to the sensors.

The method of the invention can thus be implemented with industrial sensors that are commercially available. Such sensors generally offer very good measurement accuracy, typically better than 1%, and therefore the error relating to the mixture ratio can be less than 1%. With the method of the invention, the measurements are taken non-intrusively, without tapping any gas. The method is applicable for a wide temperature range, typically from -50°C to +90°C, which corresponds to the

extreme operating conditions under which certain gas-insulated high-voltage switchgear operates.

Naturally, the method of the invention is applicable for gas mixtures having two components different from N_2/SF_6 or from CF_4/SF_6 provided that the accuracy of the sensors is chosen appropriately as a function of the differences in the molecular masses of the two components. The invention is also applicable to a gas mixture having more than two different components.